TSUNAMI RUN UP IN COASTAL AREAS: A METHODOLOGY TO CALCULATE RUN UP IN LARGE SCALE AREAS

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Although Tsunamis are a relatively infrequent phenomena represent a larger threat than earthquakes, hurricanes, and tornados and have caused more than 420,000 casualties since 1850. Recent advances in the understanding and forecasting of Tsunami impacts allow the development of adaptation and mitigation strategies to reduce the risk on coastal areas. In this paper it is presented a methodology to obtain reliable numerical results of tsunami run-up. This new methodology is based on the parameterization of both bathymetry and tsunami waves. The bathymetric profile of the coastal shelf presents a very large range of geometric variability along the world coasts. Therefore, the present study proposes a parameterization of the world coastal profiles with five relevant geometric parameters, based on the observation of random samples of real bathymetric profiles in the world. On the other hand, the generation of the tsunami incident wave is proposed to be obtained by numerical simulation of faulting mechanisms, and it is parameterized by 2 variables: The period and the height of the tsunami. Then, a tsunami run-up database is obtained, based on the combinations of those seven parameters (5 for the geometry and 2 for the wave). In order to carry out the necessary numerical simulations to develop the run-up database it has been designed a numerical flume formed with the coupling of a 2DH model based on shallow water equations with a 2DV model based on RANS equations. Interpolation based on radial basic functions is proceed on the database in order to predict run-up values of given profiles.

Keywords: tsunami; run-up; COMCOT, model coupling

INTRODUCTION

Although Tsunamis are a relatively infrequent phenomena represent a larger threat than earthquakes, hurricanes, and tornados and have caused more than 420,000 casualties since 1850. Recent advances in the understanding and forecasting of Tsunami impacts allow the development of adaptation and mitigation strategies to reduce the risk on coastal areas. In order to study the risk of tsunami flooding on coastal areas the hazard and vulnerability must be considered. The hazard is based on the inundation of the tsunami waves produced by earthquakes. There are two methods to estimate the flooded area due to a tsunami; both methods require the numerical simulation of the worst scenarios. The former solves the shallow water equations using a moving boundary scheme that allows calculating the inland limit of the flooding. The latter, estimates the Run up using empirical formulations i.e. Synolakis (1987), which depends on the tsunami wave height before reaching the coast. The first method requires time consuming simulations and high resolution topography. These limitations restrict the use of this method to small areas. On the contrary the second method can be used for large areas due to the faster simulations and no limitations on topography resolution. In this work an extension of the second method is proposed. This new method is based on the simulation on a numerical flume of reduced number of selected cases to create a Run-up transference function, and then use it to obtain the Run-up of a random profile by means of non-linear interpolation**.**

NUMERICAL FLUME DESCRIPTION

The numerical flume used in this study is a 2D vertical channel, based on the coupling of COMCOT model (Liu et al., 1998) and IH2VOF model (Lara et al., 2006). The COMCOT model is a 2DH model that solves the non-linear shallow water equations. COMCOT model works properly offshore when non linearity effects are less important. But when the wave reaches the coast, as this model does not include an adequate turbulence modeling for breaking wave’s phenomenon, the results of the inundation are less accurate. In order to improve the calculations on the flooded area the coupling of COMCOT and IH2VOF models has been carried out. Thus, the IH2VOF model solves the 2DV Reynolds Average Navier-Stokes equations (RANS) with a turbulence closure model. Figure 1 shows a scheme of how the

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coupling between both models is done. The COMCOT model is used to create the wave, and propagate it close to the coast, while the IH2VOF is used to complete the simulation and flood the coast.

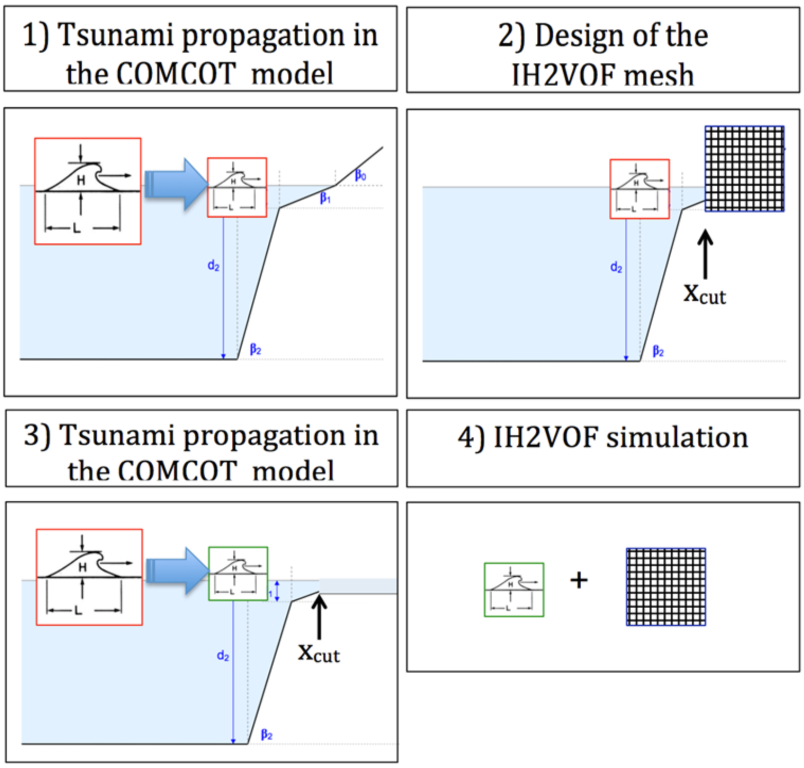

Figure 1. Description of Numerical Flume.

IH2VOF model is computationally quite expensive. Therefore, first, a propagation of the tsunami wave using COMCOT numerical model is carried out in order to delimit approximately the area that will be flooded and that, therefore, must be covered with IH2VOF (Figure 1.1)). Selecting the exact area allows us to be computationally more efficient.
Secondly, taking into account the dimensions that have been calculated for the IH2VOF mesh, the grid itself is designed, setting its limit offshore (Xcut, figure 1.2)).
After that, the wave is propagated again using COMCOT numerical model until the Xcut point (figure 1.3)). And finally, COMCOT output data at that point is used as input data for the calculation of the inundation with IH2VOF (figure 1.4)).
Both COMCOT and IH2VOF are models that have been widely validated in the past with real events**.**

METHODOLOGY

The methodology consists on: 1) Characterization of a large number of coastal profiles, 2) Characterization of tsunami waves, 3) Run-up database creation, 4) Application to calculate run-up on any new profile.

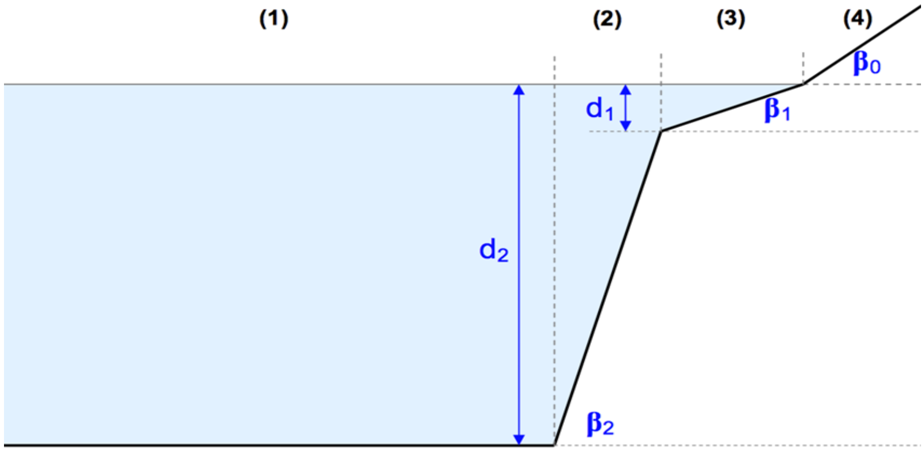

Figure 2. Characterization of coastal profiles.

Characterization of world profiles

Based on GEBCO bathymetry database, hundreds of coastal profiles have been selected worldwide. A characterization of this large number of coastal profiles based on 5 parameters (3 slopes and 2 depths) has been carried out, as it is described in figure 2. β2 is the slope from deep ocean to the coastal shelf, β 1 is the slope from the top of the coastal shelf to the shoreline and β0 is the slope onshore, from the shoreline to 50 meters high. On the other hand, d2 is the depth offshore and d1 is the depth at the beginning of the continental shelf. To reduce the number of profiles it has been done a selection of them, by applying the maximum dissimilitude technique (a description of this technique can be found on Camus et al., 2011). The result of this technique is the reduction of the database to a 50 representative beach profiles.

Characterization of tsunami waves

Based on numerical simulations using COMCOT numerical model, a set of 11 Tsunami waves were characterized by 2 parameters: the height (H) and period (T).
The periods range from 5 to 35 minutes and heights from 0.2 to 1.6 m.

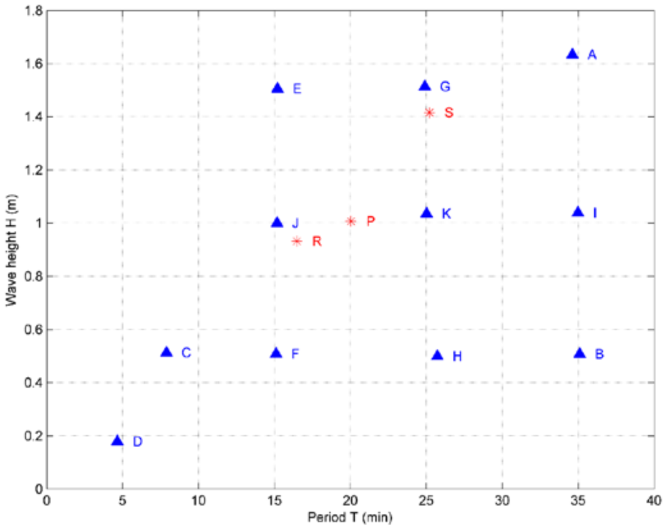

Figure 3. Height and Period of characterized tsunami waves

Run-up database creation

In order to create a database, every wave was simulated on every one of the profiles on the numerical flume. Run-up measurements were done on every simulation. Therefore, the database consists of a 7th dimensional space in which Run up is mapped.

Application to calculate run-up at any new profile

The resulting database is used to interpolate any specific tsunami wave on the corresponding profile. The interpolation is done by means of radial basis functions (RBFs), using the 7 parameters that characterized the propagation: 5 parameters for the profile and 2 parameters for the wave. A description of the use of this technique can be found on Camus et al., 2011.

APPLICATION TO REAL CASE

The results of this new methodology have been compared with three more approximations to the run-up value: Synolakis formula, numerical model with low resolution data and numerical model with high resolution data. The numerical model that has been used for these simulations is COMCOT.

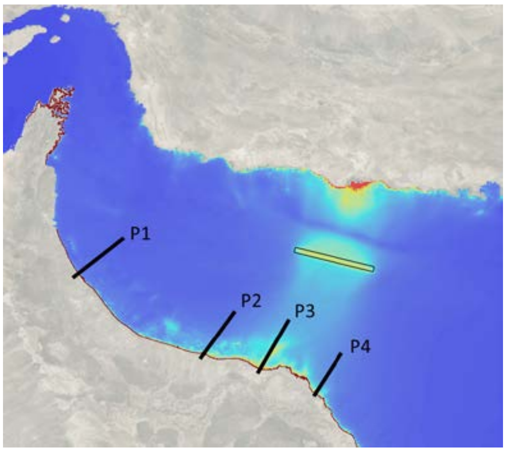

Figure 4.Source and profiles used to compare results for run-up among methods

The comparison has been made for an event of Mw=7.5, with epicenter on Makran subduction zone in Oman Gulf (figure 4). The results for these 4 methods have been compared along 4 profiles on the coast of Oman. In the next table the results of the run-up with each one be observed:

Table 1. Comparison among methods to calculate run-up (in meters). (HR=High resolution topobathymetry, LR low resolution)

Profile ID	HR (Δx=40m)	LR (Δx=280m)	Synokakis formula	New methodology
1	1.51	2.51	2.45	1.6
2	8.57	10.69	4.75	8.65
3	6.4	7.3	5.8	6.81
4	3.2	5.2	2.5	3.54

It is considered that the high resolution topobathymetry numerical modeling is the most accurate method among them. But this methodology is computationally very expensive. As it can be observed, the new methodology that is explained here is quite a good approximation to the high resolution numerical modeling.

CONCLUSIONS

The numerical simulation of the flooded area in case of tsunami at National scale, use to be difficult due to lack of high resolution data at that scale and due to the high computational cost. This works presents a new methodology based on the creation of a run-up database that allows the user to calculate the run up by interpolation, using as input the geometric characteristics of the bathymetric profile and the main parameters of the propagated tsunami wave.

The creation of the database that feed the tool has been made by using a coupled numerical model that combines the accuracy offshore of a shallow water equations model (COMCOT) with the accuracy near the shoreline of a RANS model (IH2VOF). This coupled model is used as a numerical flume where tsunami waves have been propagated along parameterized profiles. This parameterization has been made using five parameters, taking into account the slopes and the depths at different locations of the profile.

The values of run up that has been calculated using this new methodology have been compared with other methods, and the results show that this approximation made with a pre-computed run-up database is consistent.

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